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CONTENTS

	PAGE
Recent Advances in Soil Physics ...	165
The Neotropical Cornstalk Borer, *Diatraea lineolata*, Walk., and the Sugar-Cane Moth Borer, *D. Saccharalis* (Fabr.), as Maize Pests in Trinidad, with Notes from Grenada	167
Soil Conservation work in Puerto Rico ...	174
Review	175
Cork Substitute	175
Witches' Broom Disease Investigations ...	176
Application of Nitrogenous Manures to Cotton	181
The Effect of Different Localities on the Growth of Sugar Cane Varieties ...	182
The Ripening Cocouut	183
Chemical Notes	184

THE IMPERIAL COLLEGE OF TROPICAL AGRICULTURE, TRINIDAD, B.W.I.

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RECENT ADVANCES IN SOIL PYHSICS

IN an article which has just been published in *Soils and Fertilizers** recent advances in soil physics are discussed by E. W. Russell. The studies reviewed include among others recent work on soil structure and soil cultivation.

Regarding soil structure the various methods available for measuring the water stability of soil structure and the considerations that determine the technique to be chosen have been discussed by Russell and Tamhane (1) while Redlich (2) and Swanson and Peterson (3) have developed the technique for the actual field structure of a soil by direct microscopic observations on prepared thin sections. The latter workers have shown that the pore-size distribution determined in this way is in reasonable agreement with that found by direct suction, while the method has the advantage that it is possible to study the shape of the pores as well.

The mechanisms by which the incorporation of organic matter can improve the soil structure are now probably understood in a general way. Geltzer first showed that the structure-improving power of added organic matter depended on its decomposability. Organic matter itself may have no effect on structure, but either micro-organisms or their products of metabolism may act as structure improvers (4). Fungi produce aggregates by their mycelia mechanically entrapping soil particles together. Bacteria are only effective if they produce gum or mucus. Their effectiveness is increased by anything that increases their gum production, such as a high carbohydrate-nitrogen ratio. Sucrose added to soil is an excellent soil improver in the presence of gum-producing bacteria (5). Since both fungal mycelia and bacterial mucus decompose in the soil, the good soil structures they build up cannot last long after the initial decomposition of the added organic matter.

Work on the influence of rotations, leys, manure, etc., on the water-stable soil structure has given results in accordance with expectations. The quantity of water-stable aggregates increases linearly with the amount of organic matter added (6) and with increasing organic-matter content under various systems of rotation and manuring (7). Cultivation tends to destroy the structure,

*Soils and Fertilizers, Vol. VI, No. 2, 1943.

but good rotations which include the use of leys and farmyard manure can preserve a soil structure not markedly inferior to the virgin condition (8).

Childs (9) has measured the stability of the soil structure by determining the pF curves before and after a soil has had a series of wettings and dryings. By plotting the rate of change of moisture content with suction against the suction he obtains the distribution curve for the size of the soil pores, and determines the decrease in the percentage of coarser pores by this treatment.

Jamison (10) and Russell (11) have both determined the pF curves for soils up to suctions of 40 and 120 cm. of water respectively (pF 1.6 and pF 2.3), and both make use of the pore-size distribution curves as obtained above. The former, working on a Dunkirk silty clay loam in Ithaca, N.Y., showed how bringing a soil into arable cultivation from a long ley reduced the proportion of soil pores in this range; while the latter, working on a Marshall silt loam in Iowa, showed that even a ten-year blue-grass ley did not improve the pore-size distribution in this range very much compared with ten years' cropping with maize, either continuously or in rotation.

The problems of soil cultivation that have received attention recently fall into three groups: the preparation of the seed bed, the intertillage of wide-spaced crops and the use of straw and other mulches. The principles underlying seed-bed preparation under English conditions have been discussed by Russell and Keen (12) who showed that the great benefit of starting seed-bed preparation with a mouldboard plough instead of other implements, such as the rotary cultivator, is that it is a more efficient weed controller, since the crowns of perennial weeds and weed seeds are buried at the bottom of the furrow, and, further, that the virtue of deep ploughing lies at least in part in the deeper burial of weeds. These results have received support from experiments made by Ferrant and Sprague (13) on red clover, and Bushnell (14) on potatoes.

The most spectacular advances in seed-bed preparation have been made for semi-arid conditions in America, due to the work of Duley and Russell in particular. It has been shown (15) that under conditions of bright sun, and possibly torrential storms, crops will germinate and grow better if the soil is protected by a mulch of straw or other material. The soil is kept cooler (16), the soil surface more permeable (17) and less libale to wind and water erosion. Duley and Russel (18) have been developing "sub-surface tillage," which is a method of preparing a seed bed about 1-4 inches below the surface soil, which is left uncultivated. All the stubble or straw of the previous crop can be left lying on the surface to act as a mulch, all the roots of the perennial weeds are cut just below the soil surface, and the seed for the following crop is put in a fine but protected seed bed. The necessary machinery for doing this work is now beyond the stage of initial experimental development.

The main conditions governing the proper ways of cultivating a growing, wide-spaced crop are now fairly well established. During the last few years papers dealing with sugar beet (19) and potatoes (20) in England, tea (21) in Ceylon, cotton (22) in the Sudan Gezira, and maize (23) in South Africa have all shown the great importance of controlling weed growth, particularly in the early stages of plant growth. Sometimes the reason for this appears to be that the crop is much more sensitive to competition for available nitrogen when young. Cultivations to get rid of weeds should normally be as shallow as possible to minimize root injury to the crop and, once the crop is well established, just sufficiently frequent to keep the weeds from spreading. The use of a surface mulch as such appears to be mainly to keep the soil surface permeable, though Baver and Farnsworth (24) found that rotations including farmyard manure or leys may be an adequate substitute for mulching.

References

(1) *J. Agric. Sci.* 30, 1940 (210-234).
(2) *Soil Sci.* 50, 1940 (3-13).
(3) *Soil Sci.* 53, 1942 (173-185).
(4) Martin & Waksman, *Soil Sci.* 50, 1940 (29-47); 52, 1941 (381-394). Myers, McCalla & Jones, *Proc. Soil Sci. Soc. Amer.* 5 (1940), 1941 (254). Peele, *J. Amer. Soc. Agron.* 32, 1940 (204).
(5) Myers & McCalla, *Soil Sci.* 51, 1941 (189-200). Peele & Beale, *Proc. Soil Sci. Soc. Amer.* 5 (1940), 1941 (33-35); and *Proc. Soil Sci. Soc. Amer.* 6 (1941), 1942 (176-182).
(6) *Proc. Soil Sci. Soc. Amer.* 6 (1941), 1942 (96-97).
(7) *Proc. Soil Sci. Soc. Amer.* 6 (1941), 1942 (86-90).
(8) *Proc. Soil Sci. Soc. Amer.* 6 (1941), 1942 (98-103); and *Soil Sci.* 51, 1941 (201-212).
(9) *Soil Sci.* 50, 1940 (239-252); 53, 1942 (79-92).
(10) *J. Amer. Soc. Agron.* 34, 1942 (307-322).
(11) *Proc. Soil Sci. Soc. Amer.* 6 (1941), 1942 (108-112).
(12) *J. Agric. Sci.* 31, 1941 (326-347).
(13) *Soil Sci.* 50, 1940 (141-161).
(14) *J. Amer. Soc. Agron.* 33, 1941 (823-828).
(15) See, for example, Hendrickson & Crowley, *J. Amer. Soc. Agron.* 33, 1941 (690-694); Glendening, *J. Amer. Soc. Agron.* 34, 1942 (797-804); Borst & Woodburn, *U.S.D.A. Tech. Bull.* 825 and *Agric. Engng.* 23, 1942 (19-22).
(16) Alalykin, *Trudy Gor'k. S.-Kh. Inst.* 2, 1939 (137-146), quoted from *Pedology* No. 11, 1940 (105).
(17) Duley & Kelly, *U.S.D.A. Circ.* 608, 1941.
(18) *U.S.D.A. Misc. Publ.* 494, 1942. Also *Proc. Soil Sci. Soc. Amer.* 6 (1941), 1942 (484-487); and *Agric. Engng.* 23, 1942 (39-42). See also Carter & McDole, *U.S.D.A. Farmers' Bull.* 1917, 1942.
(19) Russell, Keen & Mann, *J. Agric. Sci.* 32, 1942 (330-337).
(20) Pereira, *J. Agric. Sci.* 31, 1941 (212-231).
(21) Eden, *Emp. J. Exp. Agric.* 8, 1940 (269-279).
(22) Crowther, *Emp. J. Exp. Agric.* 11, 1943 (1-14).
(23) Ekstein & van der Spuy, *Farming in S. Africa* 16, 1940 (51-52, 56). Hofmeyr, *Farming in S. Africa* 17, 1942 (721-726).
(24) *Proc. Soil Sci. Soc. Amer.* 5 (1940), 1941 (45-48).

THE NEOTROPICAL CORNSTALK BORER, DIATRAEA LINEOLATA, WALK., AND THE SUGAR-CANE MOTH BORER, D. SACCHARALIS (FABR.), AS MAIZE PESTS IN TRINIDAD, WITH NOTES FROM GRENADA

BY

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1. Introduction

OBJECTS AND SCOPE OF INVESTIGATION

THIS paper is a condensed account of a report for the Imperial College of Tropical Agriculture on the corn-borers of Trinidad and Grenada, B.W.I., made by the writer.

The work followed on that of Hynes (1942) who discovered that *Diatraea* spp. could be of considerable importance to the maize crop grown on the College Farm, and the object of the present investigations was to discover firstly whether the pests were serious throughout the island—the damage caused by them not being very evident at first sight—secondly, to work out the life histories of the borers with a view to discovering any weaknesses which would facilitate control should this at any time prove necessary, and thirdly, to discover which of the two species attacking maize was the more important.

The work was carried out during the latter half of 1942 and the first half of 1943, using the Imperial College of Tropical Agriculture as headquarters. Surveys of infestation by borers were made over the greater part of the western half of Trinidad during the two main growing seasons, and a similar survey was made in Grenada during the second season. In Trinidad, the main crop is planted at the beginning of the rains (May to June) and harvested in October or November, while the second crop is planted immediately after the first harvest and is reaped at the beginning of the dry season in January or February. Planting dates in Grenada correspond with those in Trinidad, but the second crop is of far less importance there.

The amount of damage done by *Diatraea*, during the present investigations at any rate, was not found to be serious in either Trinidad or Grenada, and it has been decided not to publish the extensive data obtained. It was, however, found that the borers were more prevalent in the north of Trinidad than in the south, the difference being highly significant statistically. There was found to be no seasonal variation in the prevalence of borers during the period investigated, the second crop being attacked to approximately the same degree as the first, contrary to the suggestion of Hynes (1942). The report containing the data referred to can be consulted in the College Library.

2. The Species Involved

D. saccharalis has a very wide range of host plants including most cultivated and many wild grasses. *D. lineolata* on the other hand is almost confined to maize, being in all probability a primitive pest of that plant (Myers, 1932) although it has been found attacking teosinte (Pickles 1935, Box, 1935a) and has been taken quite commonly therein by the writer.

D. saccharalis has a wide geographical range, extending from the southern United States to northern Argentina, while *D. lineolata* is restricted to Central America and certain of the Caribbean Islands* (Box, 1931, 1935a). In view of the restricted habits and distribution of this latter species, a standard English name of the Neotropical Cornstalk Borer is proposed here for the first time.

Descriptions of all stages of *D. saccharalis* have been made by several authors, but much confusion existed with regard to the identification of adult *D. lineolata* until the matter was cleared up by Box (1931).

The larvae of *D. lineolata* in maize would appear to be quite undistinguishable from those of *D. saccharalis* which in Trinidad tend to have paler heads than in sugar cane (Hynes, 1942), and the writer has failed to note any difference in chaetotaxy or the shape of the mesothoracic plate. Larvae with darker brown heads did occur in maize, and these gave adult *D. saccharalis* on rearing, but as far as could be determined, larvae with lighter brown heads (which comprised the vast majority) also gave some *D. saccharalis* adults on rearing. In maize in Grenada *D. saccharalis* larvae did have dark heads. Young larvae of both species have shiny black heads, and the only method of distinguishing the two species was by rearing them through to the adult stage.

Box (1931, 1935a) states that the larvae of *D. lineolata* are entirely without spots, but Hynes (1942) showed that this is merely a phase which occurs under dry conditions. Unspotted larvae, however, appear to be all *D. lineolata*, since no unspotted larva yielded *D. saccharalis*, either in the present investigations or in those of Hynes.

3. Life Histories

The life histories of *D. lineolata* and *D. saccharalis* in Trinidad maize are very similar, and it is hoped to give a full account of them in a separate paper (Kevan, 1943b). The salient features of the life history of *D. lineolata* are as follows:—The eggs are laid on the uppermost leaves of the maize plant, or later, after tasselling

* Cuba, Nassau, Trinidad and Grenada. The writer failed to discover *D. lineolata* in Grenada, but two specimens were obtained from near Plymouth, Tobago (one larva and one pupa, 4th April, 1943.)

on the sheaths of the young cobs. The young larvae feed on the leaves up to the third instar, after which they begin to burrow in the stems—or occasionally in the cobs—which they seldom leave after once entering. Pupation takes place within a chamber bored in the stalk.

The first symptoms of attack are transverse rows of tiny holes in the leaves (Fig. 1) giving way later to the frass-holes of the larvae boring in the stem (Fig. 2) and finally to the exit holes which become obvious only after the emergence of the adult moths. The duration of the life cycle from egg to adult is about seven to nine weeks, and there are six to eight larval instars.

In dry stalks, the larvae of *D. lineolata* enter a resting stage during which they lose their spots and may moult once ort wice more (Hynes, 1942). These resting larvae remain quiescent in the stalks throughout the dry season (Fig. 4), and with the onset of the rains some months later, they resume activity and pupate (Fig. 4) and are thus able to carry over the period during which the host plant is absent. *D. saccharalis* which has many alternate hosts has no need to enter a resting stage, and as far as is known, does not do so.

4. Nature of Damage to Maize by *Diatraea*

Damage in Trinidad is of two types: the reduction of the young cobs to a rotting mass, and the tunnelling in the stems which may cause considerable loss.

The damage to the young cobs is of practically no importance since there are always several incipient ears in Trinidad maize, only one or two of which develop, and unless, which is most unlikely, all the young cobs are destroyed in this manner, this destruction of incipient ears does not materially affect the crop. Damage done to the grain by externally feeding *D. saccharalis* is negligible (Hynes, 1942).

The chief damage caused by *Diatraea* in maize is, of course, the tunnelling of the larvae in the stems. This so weakens the plants that there is a tendency for them to break over in the wind, or to be broken in cultivation—usually about one to one and a half feet fro n the ground—causing many of the cobs to lie on the ground and rot, or to be missed at harvesting. Hynes (*loc. cit.*) estimates that only one quarter of such cobs are fit to harvest, and he also points out that since break-over occurs late in the development of the maize, neighbouring plants do not benefit by the absence of their fallen companions. Break-over damage should not of course be confused with that caused by the agencies of wind and rain alone in the absence of the borers or their presence in reduced numbers. In such cases, the plants are partially uprooted, and do not break.

During the present investigations, break-over damage caused by *Diatraea* could scarcely be considered to be serious, but Hynes (*loc. cit.*) showed that damage could be of importance in Trinidad, while in Grenada (where damage was also slight), the peasants informed the writer that "worms" sometimes cause major damage to maize stalks in that island also, and Moorn (1920) reports large areas of maize as having beee destroyed by *D. saccharalis* in the dependency of Carriacou.

In addition to break-over damage, it should also be borne in mind that the reduction of vascular tissue in the stalks, brought about by the presence of the borers, may cause considerable reduction of yield owing to the consequent loss of vigour by the plants—a value which, due to the large number of interacting factors, is, as pointed out by Hynes (1942), very difficult to assess. In the United States, Neiswander and Herr (1930) working on the European Corn Borer, *Pyrausta nubilalis* Hb., showed that within a given variety of maize, there was a distinct correlation between borer population and reduction of yield.

Work done on the College Farm with regard to the effect of borers on yield (Kevan, 1943) showed that plants with larger stalks are not attacked in proportion to their bulk as compared with plants with smaller stalks: in fact the nu.nber of borers per unit weight of larger stalks is significantly less than the number per unit weight of the smaller ones. Consequently large-stemmed plants should be less prone to wind damage (being less weakened) and thus, apart from any agricultural advantage, it is suggested that the aim should be directed towards obtaining maize plants with strong, thick stems, and an investigation should be made to determine the most economic method of improving peasant maize in Trinidad.

5. History of an Attack by *Diatraea*

The history of a fairly typical attack by *Diatraea* is shown graphically by Fig. 5 and the full data are given in Table I. Random samples of 50 maize stalks were made on Field 3 of the College Farm at approximately eight-day intervals from 29th October to 29th January, and additional data for 22nd February, 22nd March and 22nd April to 18th May were also recorded, the stalks remaining in the field until after the onset of the rains. The attack was not a serious one (15 per cent. break-over being the maximum damage), but it was sufficiently heavy to give a fairly complete picture of the sequence of events taking place during an attack. Table I and Fig. 5 taken together are self-explanatory and need little comment.

The salient features demonstrated by the investigation mentioned are as follows:—Judging by the frequency curve of the young externally-feeding larvae, the adult moths would appear to be attracted most to lay eggs on maize just prior to tasselling, and scarcely at all by the time that the cobs are formed. A rough estimation of the mortality of the young larvae is in the nature of 56.25 per cent. which is probably considerably on the conservative side, since in sa.npling, many minute larvae were probably overlooked. Pickles (1936) gives a mean early larval mortality for *Diatraea* in sugar cane as 81.75 per cent.

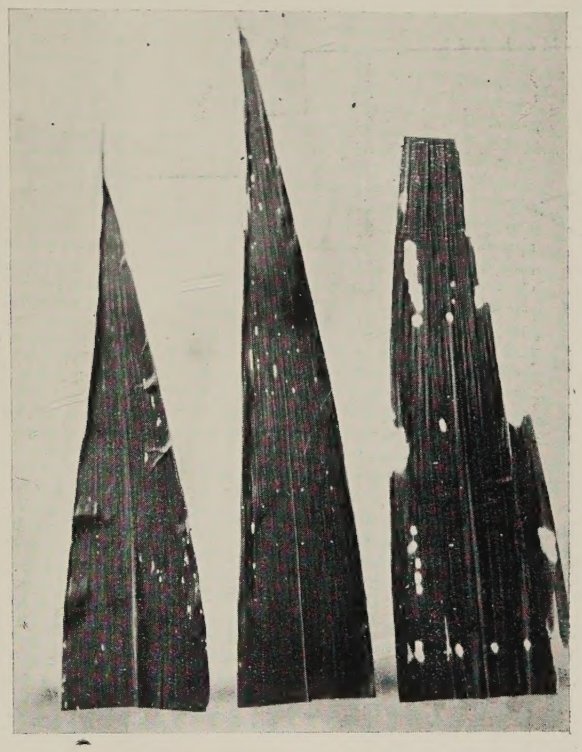

Fig. 1—Damage to maize leaves by minute larvae feeding externally. Left : skeletonization of leaf. Centre : Minute holes in rows. Right : damage by *Laphygma* for comparison.

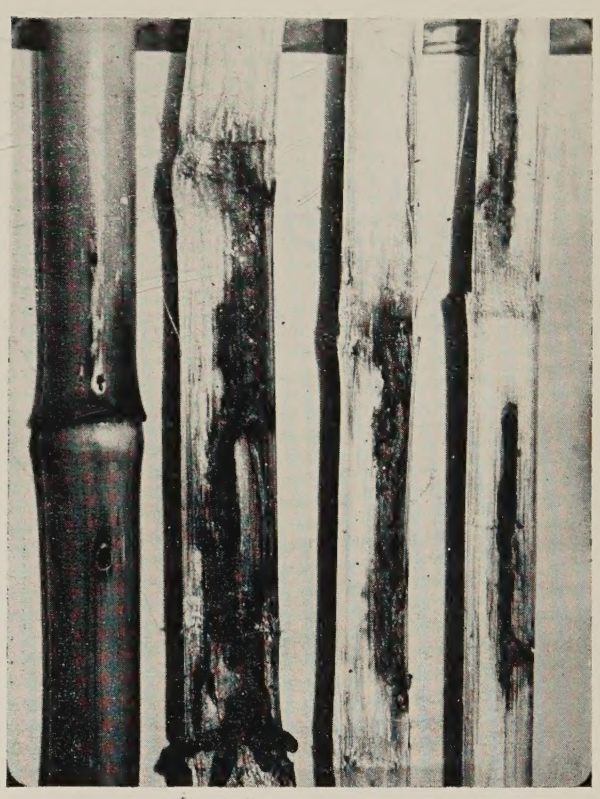

Fig. 2—Tunnels of *D. lineolata* in maize. Note exit hole and frass holes. A larva *in situ* may be seen in the second stalk from the right.

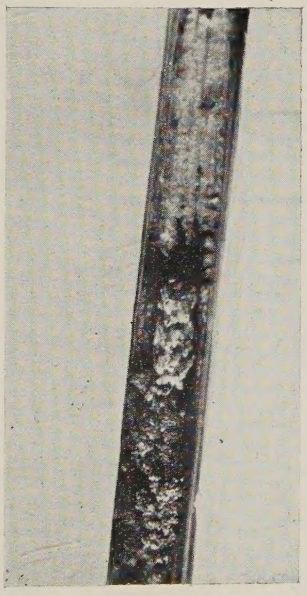

Fig. 3—Cocoons of *Apanteles diatraea* replacing *Diatraea* larvae in Teosinte.

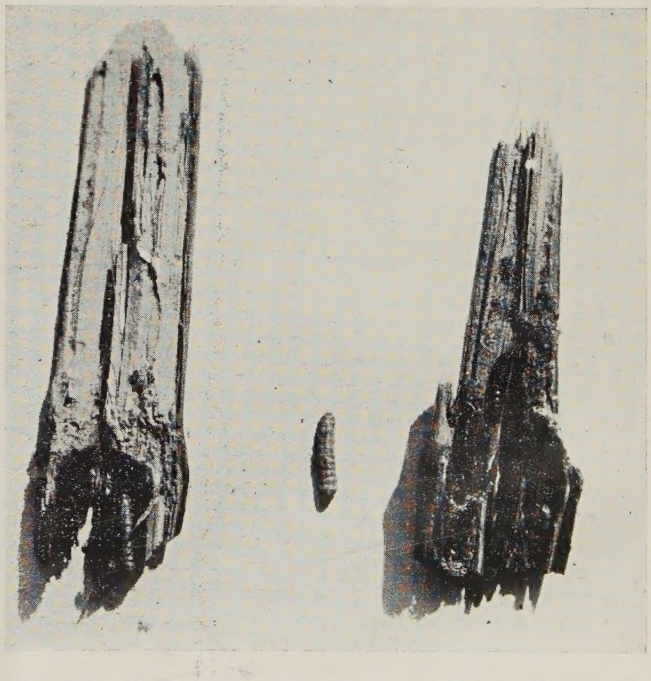

Fig. 4—Resting larvae and pupae. Left : resting larva in dry stalk. Centre : resting larva after 3 months without food in a desiccator. Right : pupae from resting larvae in a dampened stalk.

FIG. 5. THE HISTORY OF AN ATTACK BY *DIATRAEA*

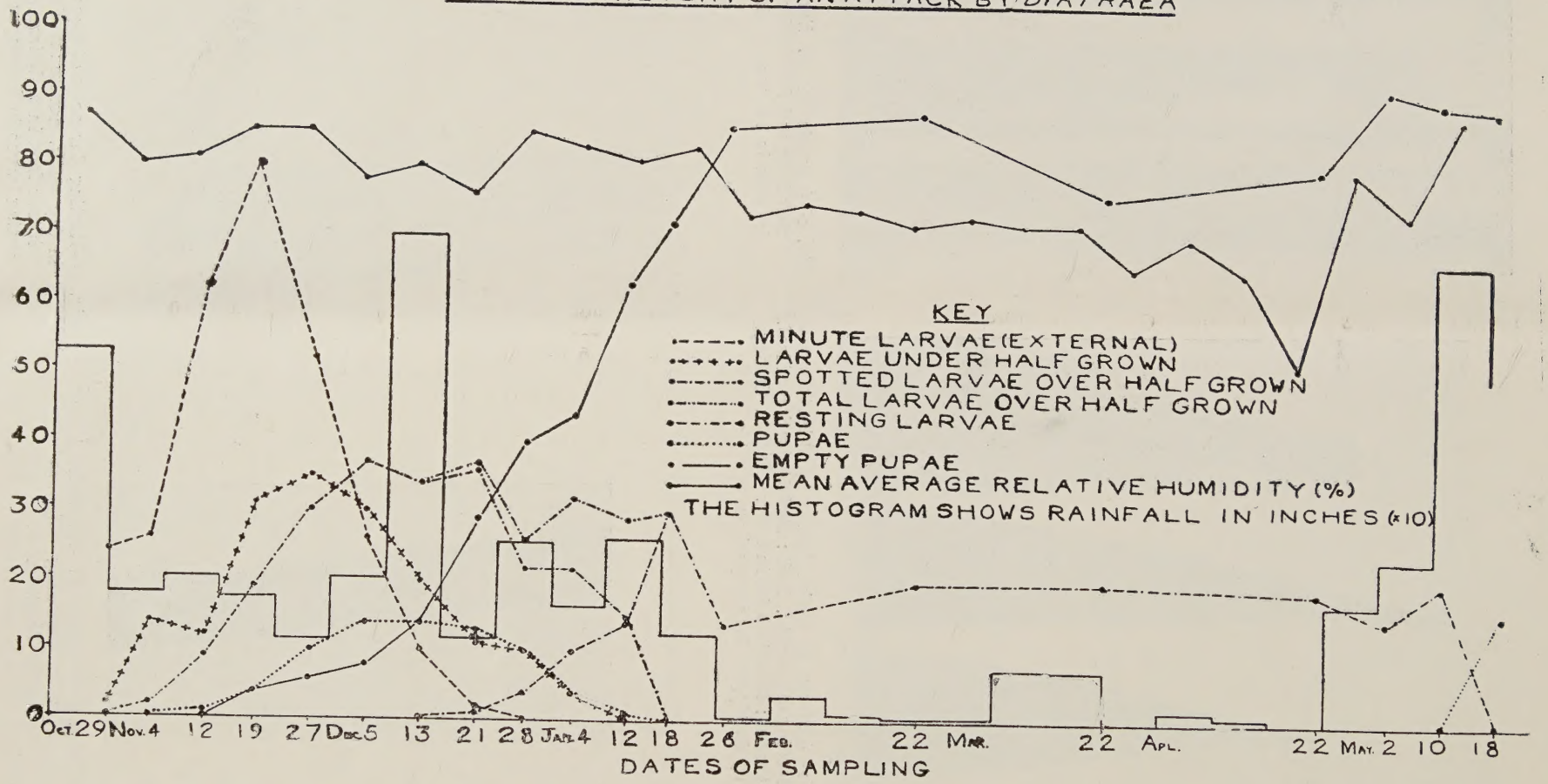

TABLE I.—History of an Attack on Field 3 of the College Farm.—50 Stalks examined per Sample

Sample Number	Apprx. Age (in weeks)	No. f External minute larvae	No. of Borers under half-grown	No. of Spotted Borers over half-grown	No. of Yellow Borers	No. of Pupae	No. of Empty Pupae	Total per 100 plants (All stages)	Total per 100 stalks excluding external larvae	Percentage of stalks bored	Total percentage Parasitism	Percentage *D. lineolata*	No. of adults reared	Condition of Stalks	Date of Sampling	Rainfall (in inches) for corresponding 8 days	Mean Average Relative Humidity (8 a.m. and 4 p.m.) for corresponding 8 days
1	6	24	2	0	0	0	0	52	4	4	0.00	—	—	Very Young	October 29	5.29	87%
2	7	26	14	2	0	0	0	84	32	26	0.00	0.0?	3	Young	November 4	1.79	80%
3	8	62	12	9	0	1	0	178	44	32	31.82	0.0	5	Young	November 12	2.02	81%
4	9	80	31	19	0	4	4	278	118	58	1.69	0.0	5	Tasselling	November 19	1.74	85%
5	10	52	35	30	0	10	6	268	164	78	1.22	20.0	5	Tasselling	November 27	1.14	85%
6	11	26	30	37	0	14	8	232	180	74	1.11	85.7	7	Tasselling-Mature	December 5	2.04	78%
7	12	10	20	34	0	14	14	192	172	90	4.65	100	6	Mature	December 13	6.98	80%
8	13	2	11	36	1	13	29	196	192	92	6.25	100	7	Mature-Dry	December 21	1.18	76%
9	14	0	10	22	6	10	40	190	190	92	8.42	87.5	8	Mature-Dry	December 28	2.56	85%
10	15	0	4	22	4	4	44	164	164	92	2.44	100 ?	3	Mature-Dry	January 4	1.67	83%
11	16	0	0	15	14	1	63	190	190	92	1.05	100	5	Dry	January 12	2.61	81%
12	17	0	0	0	30	0	72	204	204	92	0.00	100	7	Very Dry	January 18	1.24	83%
13	18	0	0	0	14	0	86	202	202	92	0.50	100	6	Very Dry	January 26	0.06	73%
																(0.37)	(75%)
14	22	0	0	0	20	0	88	216	216	92	0.00	100 ?	3	Very Dry	February 22	(0.10)	(74%)
																0.06	72%
																(0.06)	(73%)
15	26	0	0	0	20	0	76	206	206	92	3.40	100	6	Very Dry	March 22	(0.77)	(72%)
																0.76	72%
																(0.00)	(65.5%)
16	30	0	0	0	19	0	80	202	202	92	0.99	100	6	Very Dry	April 22	(0.17)	(70%)
																(0.08)	(65%)
17	31	0	0	0	15	0	92	222	222	92	1.80	100	4	Very Dry	May 2	0.00	51.5%
																(1.73)	(80%)
18	32	0	0	0	20	0	90	224	224	92	112	100	8	Damp	May 10	2.38	73.5%
																6.66	87.5%
19	33	0	0	0	0	16	89	212	212	92	0.48	100	16	Damp	May 18	—	—

The first sign of resting larvae in the stems was seen as the stalks just began to ripen and dry out, after which their numbers increased as the spotted larvae decreased in numbers to nil. Whether the figure for the number of resting larvae obtained on 18th January was unreasonably high in view of the subsequent data, or whether the following drop in numbers was due to a mortality among the resting larvae as the stalks dried out is not certain, but in the light of other data collected during the two Trinidad surveys (Kevan, 1943), the writer is of the opinion that the latter was the case.

The yellow larvae remained in the dry stalks throughout the following dry season and pupated with the coming of the rains in May. The change over from resting larvae to pupae was very abrupt —more so than was found by Hynes (1942)— though it was not until heavy rain had made the stalks thoroughly damp that this occurred. A further discussion of the resting stage will be found in a separate paper (Kevan, 1943a).

Data collected from the Trinidad surveys (Kevan, 1943) furnished corroborative evidence that the proportions of the various stages of *Diatraea* in stalks in different states of development found in Field 3 of the College Farm were correct. Much the same was found in Grenada, except that no resting larvae were found, owing to the fact that *D. lineolata* was apparently not present in any of the samples taken.

From the figures giving the percentages of *D. lineolata* obtained, it is seen that after the first five weeks of the attack, *D. saccharalis* is almost, though not completely, replaced by *D. lineolata*, and evidence from other sources would tend to corroborate this. Thus, *D. lineolata* attacks the maize rather later than *D. saccharalis*, but continues to do so for a longer period. In sugar cane, however, *D. saccharalis* is said to be commoner in more mature stems than in younger ones in Trinidad (Callan, 1942).

The data in Table I leave much of what happens with regard to parasitism during an attack open to surmise, and are far from satisfactory. The figures include both living parasties and their empty puparia or other remains, being a count of all cases of parasitism from the beginning of the attack.

The most striking figure is that of 31.82 per cent. parasitism of the 12th November sample. In addition to the parasites taken from the field, only five out of the 11 larvae reared from this sample produced adults, the other seven (63.6 per cent.) being parasitised, making a total parasitism of 63.2 per cent. Since it would appear that no infestation by *D. lineolata* in the early stages of the attack occurred, the inference would be that *D. saccharalis*, which is later replaced by *D. lineolata*, is very heavily parasitised and so kept in check, which would be one factor accounting for the predominance of the latter species. A similar state of affairs is suggested to exist in the case of *D. saccharalis* in sugar cane, for Box (1928) in a footnote, mentions that Trinidad does not suffer from *D. saccharalis* to the extent prevalent in the other West Indian islands, probably owing to the presence of numerous parasites of the larvae and eggs, as well as to the conditions under which sugar cane is grown. Callan (1942) found that of all three species of *Diatraea* in Trinidad sugar cane, *D. saccharalis* is the most attacked by *Theresia claripalpis*.

6. The Relative Importance of the Two Species

Although neither *D. lineolata* nor *D. saccharalis* was found to be a major pest of Trinidad maize during the present investigations, the species of greater importance by far is *D. lineolata*.

The first Trinidad survey showed 83.45 per cent. of the borers reared to the adult stage to be *D. lineolata*, and in the second survey the figure was 88.5 per cent. (Kevan, 1943). Evidence from the same surveys also confirmed that *D. saccharalis* attacks mainly young maize, the majority having left the stems by the time *D. lineolata* appears. It was found that 50 per cent. of the *D. saccharalis* emerged before any sign of *D. lineolata* was seen, and only 18.84 per cent. of the latter species emerged before the last *D. saccharalis* appeared.

The question of whether the growing of sugar cane and maize in close proximity affects infestation by *D. saccharalis* or not, is of importance from the point of view of possible control measures. Obviously *D. lineolata* will not be affected since it does not occur in sugar cane, but in the case of *D. saccharalis* which, although not a serious pest of sugar cane in Trinidad, would be expected to occur in it in large numbers, the position is different, since the cane-fields might act as a reservoir of infestation. The large number of host grasses of *D. saccharalis*, on the other hand it might be argued, would offset any tendency for the presence or absence of sugar cane to cause any marked difference in the numbers of that species attacking maize. The results of the surveys showed that although maize in the vicinity of cane fields did have a greater infestation of *D. saccharalis*, the difference was not sufficient to make it necessary to discourage the planting of these two crops in close proximity. *D. saccharalis*, even in sugar-cane areas, appears to be of very minor importance in maize.

Turning now to the possible alternate host plants of *D. lineolata*, a study of the literature reveals that teosinte (*Euchlaena mexicana*) is the only one previously recorded (Pickles, 1935, Box, 1935a), and since much work has already been done on the food plants of *Diatraea* (Myers, 1932, Box, 1935) it was unlikely that any other would be found. However, some investigations were made on teosinte (*Euchlaena*), adlay (*Coix*), and Guatemala grass (*Tripsacum*), which together with maize (*Zea*) comprise the tribe Maydeae.

It was found that teosinte and maize are apparently equally attractive to *D. lineolata*, the percentage of plants attacked being much the same,

although the larvae seem to thrive better on maize. Adlay and Guatemala grass were not found to be attacked by *D. lineolata* (though the numbers of plants examined were not very large—especially in the case of the latter) but they are attacked to a small extent by *D. saccharalis*. A small-scale food preference test was also made in the laboratory, using teosinte, maize and adlay. Young larvae were introduced and bored into the two former in about equal numbers, but avoided the adlay, showing this plant to be unsuitable.

7. Parasites

There is an extensive literature concerning the parasites of *Diatraea* in sugar cane throughout the New World, and a useful catalogue is given by Van Dyne (1929). Little, however, has been published concerning the parasites of *D. lineolata*.

Several species of parasites are known from *Diatraea* species in Trinidad, and Holloway, Haley *et al* (1928), Van Dyne (1929), Myers (1931), Pickles (1935), Callan (1942), and Hynes (1942) give accounts of these.

In addition to the native Trinidad parasites, attempts have been made (in 1936 and 1937) to introduce the Amazon Fly (*Metagonistylum minense* Towns.), but without success (Pickles, 1937, 1939, Cleare, 1939, Callan, 1942).

The following insect parasites of the larva, identified from specimens determined for the Imperial College of Tropical Agriculture, have been found by the writer in Trinidad maize :—

Tachinidae—*Theresia* (*Paratheresia*) sp.

Braconidae—*Bassus* (*Microdus*) *stigmaterus* Cress., *Apanteles diatraeae* Mues., (Fig. 3.), and a single empty cocoon of what was probably *Ipobracon grenadensis* Ashm.

Owing to present conditions, the specimens of *Theresia* were not sent away for expert determination. All previous records of this genus in Trinidad sugar cane are of *T. claripalpis* Wulp. while for maize, Hynes (1942) records *T. P. brasiliensis* Towns.

In addition to the insect parasites, a white *Empusa*-like fungus was found quite commonly attacking the larvae.

In Grenada, the only parasite found, apart from an empty cocoon of what was probably *Ipobracon grenadensis*, was *Apanteles diatraeae*, which is not mentioned by Myers (1935) among the parasites of *Diatraea* from that island. It is interesting to note that Myers never reared *Apanteles* from *Diatraea* in sugar cane, and that he considers it the chief, if not the only parasite, of the maize *Diatraea* in Trinidad (Wilkinson, 1930.)

The findings of the present investigation certainly indicate *Apanteles* to be one of the principal parasites of *Diatraea* in Trinidad maize, and also the most important parasite of *D. lineolata*, but whether that species has other enemies or not, is open to some doubt. Certainly *D. saccharalis*, in Trinidad maize, is commonly attacked by *Theresia*, *Apanteles* and the fungus, and apparently very heavily (*see* Section 5).

Living *Theresia* puparia have only once been taken from samples yielding 100 per cent. *D. lineolata* adults on rearing, and in this case only four moths were obtained, so the sample may not have been pure. *Bassus*, however, has been reared on three out of the four occasions on which it was found, from pure *D. lineolata* samples, and living *Apanteles* pupae have been taken four times from samples which yielded 100 per cent. *D. lineolata* adults, while the fungous parasite has been taken thus three times.

From these facts, it would appear probable that *D. lineolata* is parasitised by *Apanteles diatraeae* as reported by Myers (1935) and Hynes (1942), by *Bassus stigmaterus*, and an *Empusa*-like fungus. It seems doubtful, however, if it is parasitised by *Theresia* at all, especially in view of the fact that Scaramuzza (1939) was unable artificially to rear *Theresia claripalpis* on that species.

The total percentage parasitism of *Diatraea* in Trinidad maize is not very high—as was noted by Hynes (1942). In the first Trinidad survey (Kevan, 1943) it varied between nil and 15.5, with an average of 3.225, and in the second, between nil and 10.0, averaging 4.08 ; which figures indicate clearly that parasites do not act as much of a check, at least on *D. lineolata*.

A statistical analysis of the prevalence of parasites in *D. saccharalis* as compared with *D. lineolata* was made by correlating the percentage of *D. saccharalis* adults reared from 44 samples of maize, with the total percentage parasitism in those samples (Kevan, 1943). This gave a fair if not completely accurate indication of the importance of parasites on the two individual species. A positive correlation between the percentage of *D. saccharalis* in the sample and the percentage parasitism was obtained, and this was found to be very highly significant, showing that the rate of parasitism depends on the proportion of *D. saccharalis* present. *D. saccharalis* must therefore be much more heavily parasitised than *D. lineolata*—a fact which was indicated in Section 5.

It is interesting to note that in sugar cane, *D. saccharalis* was found by Callan (1942) to be much more heavily parasitised by *Theresia claripalpis* than either *D. impersonatella* or *D. canella*.

Taking all available Trinidad figures together, the figure for the relative importance of each of the parasites of *Diatraea* in maize were as follows : *Theresia* 46.63 per cent. ; *Apanteles*, 42.49 per cent., *Bassus*, 1.55 per cent. : *Ipobracon* (?), 0.52 per cent. : Fungous parasite, 8.81 per cent. Thus *Theresia* and *Apanteles* are about equal in importance in the two species together (though the former probably does not affect *D. lineolata*), while the others are negligible.

In Grenada, three out of the four cases of parasitism recorded were *Apanteles*, while the fourth was probably *Ipobracon*. As far as is

known, *Theresia* does not occur in that island, but it might with advantage be introduced there from Trinidad against *D. saccharalis*, as was suggested by Myers (1935).

8. Control Measures

Although during the present investigations *Diatraea* was not found to be a serious enough pest to necessitate control measures, there is always the possibility that it could be of importance, and consequently the question of control should be taken into consideration.

There are two weak points in the life history of *D. lineolata*. One is the resting stage, since the presence of dry maize stalks during the dry season is essential for the survival of the pest in the absence of growing maize, there being no known alternate host plant other than teosinte, which is grown only experimentally. The writer would therefore endorse the suggestion for the destruction of all maize stalks during the dry season and their manufacture into compost by the method advocated by Hynes (1942). A simple method of avoiding the waste and expense of turning the top layers of the heaps, would be to cover them with a layer of material other than maize (or teosinte) stalks. Attempts to grow maize during the dry season under irrigation should be discouraged; and so too, should be the growing of maize in swamp areas, such as Nariva and Oropuche Lagoon.

Were an effective closed season introduced to Trinidad, *D. lineolata* as a pest of maize would probably be almost entirely eliminated. *D. saccharalis* is of no consequence in Trinidad, which is fortunate in view of its wide range of host plants.

In Grenada, however, *D. saccharalis* can be of some importance, and the only suggestion that can be made is to attempt the introduction of *Theresia* from Trinidad in the hope that it would become more prevalent there than in its native home, though it seems very doubtful if it would.

The other weak point in the life history of *D. lineolata* is at the time when the minute externally-feeding larvae are most prevalent—that is, at the time of tasselling.

It might be of some value to use insecticidal dusts or sprays on small areas of valuable seed-corn, should these be grown in the future in an attempt to improve the local strain of maize by breeding. Before recommending this, however, experiments would have to be carried out to determine whether it would be worth while. It is suggested that two applications of the insecticide would be necessary—one about a week or so before and one up to a week after tasselling.

The most recent papers on insecticidal control of *Diatraea* are those of Ingram and Dugas (1942) and Dugas (1943), where it is stated that in Louisiana, 90 to 97 per cent. of the first generation borers of *D. saccharalis* in sugar cane were controlled by the application by power dusting machines of synthetic cryolite (Na_3AlF_6), giving four applications at weekly intervals at the rate of eight pounds per acre. Ellison and Ingram (1939) state that no dusts are effective after tunnelling has started. Cryolite apparently does not scorch sugar cane, but maize is more delicate, and there may be some danger of this.

Hinds and Spencer (1927) give accounts of testing various fluorides and silicofluorides with a view to *Diatraea* control in sugar cane and maize, and they found arsenicals to be ineffective. Strong (1936) notes that *D. grandiosella* can be treated with barium silicofluoride in valuable maize in the United States, and the same may be true for *D. lineolata* in Trinidad.

It is advocated that cultural practices should be aimed at producing strong, healthy plants less liable to break-over.

9. Summary

(1) Two species of *Diatraea* attack maize in Trinidad; they are *D. lineolata* Walk. and *D. saccharalis* (Fabr.). The borers are more prevalent in the north of the island, but there is no seasonal variation during the growing period.

(2) The standard English name of Neotropical Cornstalk Borer is proposed for *D. lineolata*.

(3) There would appear to be no method of distinguishing the spotted larvae of *D. lineolata* from those of *D. saccharalis* in Trinidad maize though the resting larvae of the former species are distinct.

(4) The life histories of the two species in Trinidad maize differ little except for the absence of a resting stage in *D. saccharalis*, a feature very conspicuous in *D. lineolata*. The more salient feature of the life histories are noted.

(5) The nature of the damage done by *Diatraea* to maize is described, although during the investigations this was slight, both in Trinidad and Grenada. Large-stalked maize is not attacked in proportion to its bulk as compared with small-stalked maize, and should therefore be less prone to wind damage. Cultural practices should aim at increasing the size of stalks as well as that of the ears, and an investigation should be made to determine the best method of improving peasant maize in Trinidad.

(6) The history of an attack by *Diatraea* is followed from its inception until well after harvesting, and it is shown that moths seem to be attracted most to oviposit on maize just prior to tasselling. On the maturing of the plants, the larvae begin to enter the resting stage, and by the time that the stalks have dried out, no larvae, other than resting larvae of *D. lineolata*, and no pupae, remain, the resting larvae carrying the species over the dry season, when they pupate with the coming of the rains.

(7) *D. saccharalis* is relatively unimportant and attacks chiefly the young stages of the maize, being in large part replaced by *D. lineolata* later on. It appears to be much more heavily parasitised than *D. lineolata*.

(8) *D. lineolata* is shown to be by far the more important species of the two attacking maize in Trinidad, but in Grenada it was not found.

(9) Corroborative evidence is given to show that *D. saccharalis* attacks mainly the younger plants, 50 per cent. emerging before the appearance of *D. lineolata*, only a small percentage of which emerges before the last *D. saccharalis*.

(10) The question whether growing maize and sugar cane in close proximity increases the number of *D. saccharalis* is considered, and it was found that it does so, but apparently not to the extent which would make it necessary to discourage the practice.

(11) Possible alternate host plants of *D. lineolata* (viz. grasses of the tribe Maydeae) were tested on a small scale, and only teosinte (*Euchlaena mexicana*) was found to harbour the species. This grass appears to be as attractive as maize but the borers would not seem to thrive so well in it.

(12) The parasites of *Diatraea* found during the investigations and their relative importance are discussed, the most common being *Theresia* sp. and *Apanteles diatraeae* Mues. The latter is recorded for the first time from Grenada, and the former, it is suggested, is more or less confined to *D. saccharalis*. Neither parasite occurs in sufficient numbers to keep *Diatraea* in check, but *D. saccharalis* is shown to be more heavily parasitised than *D. lineolata*.

(13) Possible control measures (should these prove necessary) are discussed, and it is urged that maize stalks be not left in the fields during the dry season, but made into compost, and that the growing of maize during this period be discouraged. An effective closed season would probably eliminate *D. lineolata* as a pest of maize in Trinidad almost entirely.

(14) It is suggested that valuable seed-corn—if this should be grown in the future—might be protected by the application of some insecticide, such as cryolite or barium silicofluoride, at about the time of tasselling.

10. Acknowledgments

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References

Box, H. E., 1928.—The introduction of Braconid parasites of *Diatraea saccharalis* Fabr. into certain of the West Indian islands, *Bull. ent. Res.* **18**, 365-370.

Box, H. E., 1931.—The Crambine genera *Diatraea* and *Xanthopherne* (Lep., Pyral.), *Bull. ent. Res.* **22**: 1-50.

Box, H. E., 1935.—The food plants of American *Diatraea* species, Government Printer, Port-of-Spain, 1-11.

Box, H. E., 1935a.—New records and three new species of American *Diatraea* (Lep., Pyral.), *Bull. ent. Res.* **26**: 323-333.

Callan, E. McC., 1942.—Notes on *Theresia claripalpis* Wulp. (Diptera, Tachinidae), a parasite of *Diatraea* spp. in Trinidad, B.W.I., *Trop. Agriculture, Trin.* **19**: 71-73.

Cleare, L. D., 1939.—The Amazon fly (*Metagonistylum minense* Towns.) in British Guiana, *Bull. ent. Res.* **30**: 85-102.

Dugas, A. L., 1943.—Sugar-cane borer losses and control by dusting with cryolite. *The Sugar Bulletin*, New Orleans, **21**: 106-108.

Ellison, L. O., and Ingram, J. W., 1939.—Experiments with insecticides in the control of the sugar-cane borer, *Diatraea saccharalis* (Fab.), *Proc. int. Soc. Sug. Cane Tech.* **6**: 693-705.

Hinds, W. E. and Spencer, H., 1927. Insecticidal control for sugar-cane borer, *Bull. La. agric. Exp. Sta.* **201**: 1-56.

Hynes, H. B. N., 1942.—Lepidopterous pests of maize in Trinidad, *Trop. Agriculture, Trin.* **19**: 194-202.

Ingram, J. W. and Dugas, A. L., 1942.—A summary of recent investigations of sugar-cane borer control with cryolite and other insecticides, *Bull. La. agric. Exp. Sta.* **350**: 34-49.

Kevan, D. K. McE., 1943.—Dissertation for the Imperial College of Tropical Agriculture, *Unpublished.*

Kevan, D. K. Mc.E, 1943a.—Notes on the resting stage of the neotropical cornstalk borer, *Diatraea lineolata* Walk. (Lep., Pyral.), *In preparation.*

Kevan, K. D. McE., 1943b.—The life history of the neotropical cornstalk borer, *Diatraea lineolata* Walk. (Lep., Pyral.) in Trinidad, B.W.I., *In preparation.*

Moore, J. C., 1920.—Insect pests and plant diseases, *Rep. agric., Dep. Grenada* Apl.-Dec., 1919: 6-7.

Myers, J. G., 1931.—Descriptions and records of parasitic Hymenoptera from British Guiana and the West Indies, *Bull. ent. Res.* **22**: 267-277.

Myers, J. G., 1932.—The original habitat and hosts of three major cane pests of Tropical America (*Diatraea, Castnia* and *Tomaspis*), *Bull ent. Res.* **23**: 257-271.

Myers, J. G., 1935.—An entomological investigation in Grenada, *Trop. Agriculture, Trin.* **12**: 216-226.

Neiswander, C. R., and Herr, E. A., 1930.—Correlation of corn borer population with degree of damage, *J. econ. Ent.* **23**: 938-945.

Pickles, A., 1935.—Progress reports for January to April 1935. I. Division of entomology, Sugar cane Investigation Committee, Port-of-Spain.

Pickles, A., 1936.—Observations on the early larval mortality of certain species of *Diatraea* (Lepid., Pyralidae), under cane field conditions in Trinidad, *Trop. Agriculture, Trin.* **13**: 155-160.

Pickles, A., 1937, Report of the entomologist for the year 1936, *Rep. Dep. Agric. Trin. Tob.* 1936: 50-51.

Pickles, A., 1939.—Report of the entomologist for the year 1938, *Rep. Dep. Agric. Trin. Tob.* 1938: 71-74.

Scaramuzza, L. C., 1939.—The introduction of *Theresia claripalpis* V. d. W. into Cuba and its artificial multiplication, *Proc. int. Soc. Sug. Cane Tech.* **6**: 589-595.

Strong, L. A., 1936, Report of the chief of the Bureau of Entomology and Plant Quarantine 1936, U.S. Dep. Agric., Washington, 1-121.

Van Dyne, D. L., 1929,—Parasites of sugar-cane moth borers, *J. econ. Ent.* **22**: 248-267.

Wilkinson, D. S., 1930.—New species and host records of Ichneumonidae and Braconidae, *Bull. ent. Res.* **21**: 147-158.

SOIL CONSERVATION WORK IN PUERTO RICO*

Observations made by the Soil Conservation Service at the Mayaguez Experiment Station since 1937 are more than mere recordings of the effects of torrential rains on the steep slopes of lateritic soil. Designed to ascertain the causes and effects of run-off and soil erosion, and to develop measures of control, investigations also include cultural methods and terrain reformation. Through these studies, the farmers of the island are learning to save soil, make the best use of intense rainstorms, and provide a better standard of living for their families.

Conditions of soil and climate at the experiment station are common to all the tropics, and especially to the Antilles. Slopes of the Cialitos, Catalina, and Mucara soil types vary from 10 to 60 per cent. Annual rainfall averages 82 inches with monthly variations from 2 to 11 inches. There is run-off of water from about 90 per cent. of the rainfall with a wide difference between seasons. Run-off occurs on a total of less than 10 days during the dry winter months of December, January, and February; however, there is run-off on about one out of every three days in the wet months of May through September. Although variability in rain intensity was found an important factor in causing variations in rates of run-off and erosion, vegetative and soil conditions tended to counteract and minimize the effects of increased intensity. Evidence from 374 farms showed that grass-covered plots lost much less soil than bare plots. There was an average annual soil loss of 2,321 pounds per acre in land under Guinea grass, as compared with a loss of 382,151 pounds of soil from a desurfaced acre.

The difference between the run-offs from two methods of planting sugar cane was slight, but the rates of erosion on plots planted in holes was significantly greater than the erosion on plots planted on the sides of contour furrows. The furrows acted as settling basins and there was also more even distribution of stalks across the contoured rows to check soil loss further.

Two cultural methods of growing coffee shaded by bananas were compared for relative amounts of run-off and erosion. An older method, a "ground skinning" or "pica tierra" process consisted of cutting all grass and weeds closer than 2 inches to the surface of the ground prior to coffee harvesting and at two other times during the year. By the newer method, the grass was permitted to grow uncut except for a bare ring one foot in radius about the coffee plant. Each plot was one-fiftieth of an acre in size, each had a similar density of overhead canopy formed by banana and other trees, and each had an average slope of 61 per cent. Results indicated that increases in rainfall intensities were, as usual, associated with increases in rates of erosion and proportion of rain which ran off from both plots. Studies of 115 rains definitely showed that the method of "ground skinning" the soil surface of grass and weeds three times a year was from two to ten times as wasteful of soil and water as the method wherein the grass was cut only within a foot of the coffee plants.

A study was made of 155 rains upon four non-vegetated plots, two of Catalina subsoil and two of Catalina topsoil, to determine relative effects of several variables upon the rates of run-off and erosion. The results showed that for a given amount of rainfall under these conditions the amount lost as run-off depends largely upon the variations in degree of slope, in the amount of organic matter present in the soil and in the amount of moisture in the soil before the rain. On the other hand the survey indicated that differences in soil porosity, specific gravity, per cent. of clay and finer material and certain indexes of susceptibility to washing were not related to differences in rates of either run-off or erosion.

Another study showed that variations in rainfall intensities and soil moisture before rains accounted to a large degree for the variation in the rate of run-off from two Guinea-grassed plots. Here, too, variations in the specific gravity of the soil, in soil porosity and in the duration of rains, as well as influences of overhead canopy and of total rainfall per rain, were shown to be of doubtful importance in explaining the variability in run-off. Variations in the organic content and the slope gradients of Guinea-grassed plots were not great enough to be considered in the calculations.

* Abridged version of an article by L. F. Thomann published in *Soil Conservation*, Vol. 8, No. 12, 1943.

Greatest effect upon variation in rates of erosion from the grassed plots resulted from differences in rates of run-off, and of slightly less consequence was variation in overhead canopy. There was however no significant effect upon rate of erosion due to variation in duration or intensity of rains, moisture content of the soil before the rains, specific gravity of the soil or soil porosity. Effect of variability of total rainfall per rain upon erosion rates also was of doubtful importance.

Major objectives of experiments with grass and legume mixtures on the research station plots have been to determine which species will increase density and herbage production in order to reduce soil erosion and cut feed costs. Trailing indigo gave excellent results in mixed planting with other species, with the exception of Para grass and Wandering Jew. A mixture of trailing indigo and Barbados sourgrass apparently is well adapted for dry areas of Puerto Rico since both are drought-resistant.

Trailing indigo proved better than wild grasses as a soil binder below stiff-stemmed grass barriers on banks of bench terraces constructed by normal ploughings, although it was shown to be inferior to centipede grass, African digitaria grass and molasses grass as a soil binder. Yielding up to nine tons of green matter a year, trailing indigo compared favourably with several species, including molasses grass, Cogon grass and Manila grass, from the standpoint of high forage productivity and usefulness in soil erosion control.

Results at Mayaguez to date show that pasture grasses have required nitrogen fertilization and that highest yields were secured when a nitrogen phosphate-lime combination was used. However, the observations are being continued over a longer period of time to obtain more conclusive data on this phase of the pastures project.

Experiments have been carried out on the formation of bench terraces on 2 to 45 per cent. slopes. It has been found that 80 per cent. of the earth movement can be accomplished by normal plowings for field crops if a $4\frac{1}{2}$- to 5-foot vertical interval is used between stiff-stemmed plant barriers. Of 5 plants tested for this barrier use, elephant grass ranked best and was followed in order of rank by Guatemala grass, sugar cane, sorghum and bamboo. Terrace banks 2 feet high were formed in 2 years by making 8 plowings causing fill above the terrace and 4 plowings producing cut below the bank. Banks, nearly 3 feet high, were produced in 2 years by 4 plowings above the barrier and by 12 plowings below the barrier line.

Based upon observations at Mayaguez, a bench-terraced acre of lemon grass should produce more than 50 pounds of oil each year. If distilleries for processing the oil were started on the island, it is anticipated that the grower's 40 per cent. of the oil would return him an annual gross profit ranging up to as high as $70 per acre.

Experiments with soybeans also have been carried out on the research plots. Of 10 different kinds tested, the Clemson and Creole varieties of this vital war crop produced the highest quality and the greatest quantity of seed.

REVIEW

AN INTRODUCTION TO HISTORICAL PLANT GEOGRAPHY.

By E. V. Wulff, Waltham, Mass., The Chronica Botanica Co., London, W.1., Wm. Dawson & Sons Ltd. Price : $4.75.

The scope of this work may best be indicated by quoting from the Foreword (by E. D. Merrill) "It constitutes the first part, covering general and theoretical problems, of a projected three volume work on historical plant geography. The second part, devoted to a History of the Floras of the World, was completed and, at the outbreak of the present war, ready for publication under the auspices of the Academy of Sciences of the U.S.S.R. in Leningrad. The third part, dealing with the changes in floras caused by man's activities, is in the course of preparation . . . . The present volume consists of eleven chapters opening with one covering the scope of the subject, the relationships to allied sciences, and methods of investigation, and closing with an excellently prepared one on the concept of floral elements. Between these two chapters, in much detail, is considered the history of the science, areas : their types and origins, parallelisms in the geographical distribution of plants and animals, artificial and natural factors in relation to the geographic distribution of plants, migrations of species and of floras and their causes, and the historical causes for the present structure of areas and the composition of floras".

The present reviewer has not read the book but having spent several hours dipping into it estimates that it might perhaps be conscientiously digested in about a week. It is pedantically thorough, unquestionably valuable for that reason, and no doubt destined to be a standard work of reference. E. E. C.

CORK SUBSTITUTE

It is reported that cobs (cobs without grain) of the Indian maize form a good substitute for the corks if properly finished (L. D. Mahajan, *Science and Culture*, 1942, 8, 139). These cobs are conical in shape, light in weight, and compressible in structure. The cobs are cut into pieces of desired length, their rough surface smoothed with sand paper and then they are soaked in molten paraffin for a minute or two. Corks so prepared have sufficient resilience as well.—(*Current Science*, Vol. 11, No. 10, pp. 385-418.)

WITCHES' BROOM DISEASE INVESTIGATIONS

V. Large-scale Experiments on Direct Control

BY

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Introduction

OBSERVATIONS made since 1930, have shown that there are certain seasonal maxima and minima in the manifestations of Witches' broom disease (*Marasmius perniciosus*) in Trinidad. The data establishing the annual periodicities in production of brooms, and of the sporophores (mushrooms) on the brooms, have been described and discussed by Baker, Crowdy and Thorold (1). The authors considered that certain modifications of the current attempts at direct control of the disease were indicated, in view of the consistent annual rhythms of broom and mushroom production. It was desirable to test the possibility of control along such lines, by large-scale experiments. Accordingly, a general scheme of experimental procedure was prepared by an informal committee comprising the Acting Director and officers of the Department of Agriculture, and the Principal and members of the staff of the Imperial College of Tropical Agriculture. The Cacao Board approved of the scheme prepared and provided funds and staff for carrying out the experiments under the general direction of the writer.

Previous Attempts at Direct Control

Witches' broom disease was first recorded for Trinidad in May 1928 and was proclaimed under the Plant Protection Ordinance in August of the same year, later being made notifiable in June 1929. Unfortunately, there was a steady decline in prices paid for plantation cacao from the time when the disease was first observed (2). Consequently, owing to the depressed finances of cacao estates at that time, it was impracticable to insist on their achieving such standards of efficiency and expenditure in the destruction of brooms as the rapid spread of the disease seemed to require. A staff of inspectors reported on the incidence and spread of the disease and at the same time endeavoured to persuade owners and occupiers to search for and destroy the brooms. The disease was steadily spreading and increasing in intensity in 1932, when F. Stell, Mycologist in the Department of Agriculture, recommended that two campaigns for the removal of diseased tissue should be carried out annually (3), in an attempt to check the disease by destruction of brooms before the end of May and then again before the end of October. One such special campaign was carried out in May and June 1932 (5), when brooms were removed within an area which included 7,369 acres of cacao, but apparently without achieving any appreciable results. It was then recognised that more frequent destruction of brooms would be necessary in the very wet districts. Stell's early recommendation anticipated the lines along which the possibilities of direct control are reconsidered now in the light of a decade of witches' broom observations. Since the discovery of the disease in Trinidad, it has been appreciated that control would be largely an economic problem and that the most that could be attempted or expected would be the reduction of sporophore production to a minimum (4). It is inevitable that there will be some infected material remaining in the plantation, when a thorough removal of brooms has been attempted on an estate scale. Brooms were at first removed every month at Marper Estate. Latterly, the accepted procedure for control has been to advise the removal of brooms every two to three months (6) but this was being achieved on a negligibly small amount of the island's cacao within recent years. A certain amount of broom cutting was done on estates in connection with Cacao Subsidy Schemes during the period 1936-1941.

Witches' Broom Control Experiments, 1941-43

A period of at least three months usually elapses between the appearance of a broom and the development of the fungus sporophores (mushrooms). Therefore, if brooms were cut regularly every three months, the disease should theoretically be controllable. However, even that frequency of cutting will be impracticable and uneconomic on an estate scale under existing conditions.

The period of maximum appearance of brooms is generally in January and February. It is therefore unprofitable to remove brooms at that time because new ones are likely to be appearing so rapidly that an area cannot be cleared of brooms in one 'round'. On the other hand, if brooms are removed in the period of minimum appearance which is April to June then the area can be cleared much more effectively. It also happens that the period of March to May is generally one of minimum sporophore production, but the periodicity is less regular than in the case of broom production during the year. It seemed likely that the removal of brooms in the period April to June might be an effective control measure, especially if followed by a second 'round' in October and November, to remove brooms which had been overlooked in the previous 'round', or which had developed in the intervening period. Accordingly, experiments were started to test this method of control.

Design of Experiments

A plot lay-out was not suitable for this experiment, since it was necessary to have a large and continuous area on which the removals of brooms once or twice in the year were to be carried out. Around this area, a belt of cacao was to be maintained where no brooms would be removed. The progress of the experiment and the ultimate effect of the treatments were to be assessed by means of monthly observations on a number of marked trees taken at random within the treated and untreated areas. These areas are subsequently referred to as 'controlled' and 'uncontrolled' respectively.

Location of Experiments

The experiments have been carried out in 1941-42 and repeated in 1942-43 at the same two sites, namely River Estate in a low-level valley of the Northern Range and Phillipine Estate in the Central Range. These two estates respectively represented areas of severe and moderate incidence of witches' broom disease. Changing circumstances, including a progressive reduction in the amount of labour available for the work, necessitated some departures from the original planning and procedure of the experiments in the course of the period 1941-43.

Organization of Work on Experiments

The supervision of the removals of brooms and the recording of marked trees were undertaken in 1941-42 at River Estate and at Phillipine Estate, respectively by Messrs. Carr Brown and E. W. Hernandez, with the assistance of Junior Inspectors, under the general direction of the writer who has been in charge of the experiments throughout. Later, when the services of the Cacao Board's Inspectors were required elsewhere the writer personally supervised the recording work in 1942-43 with the assistance of other officers of the Department of Agriculture.

Experimental Procedure

At River Estate, where the incidence of brooms was relatively high, the clearing of the 'controlled' area proceeded slowly. On the average, one man could complete only twenty or fewer trees in one day at River Estate. At Phillipine Estate at least twice that number of trees could be cleared of brooms by one man in a day. It was on account of the shortage of labour and high incidence of disease that it was necessary to reduce the 'controlled' area considerably at River Estate in 1942-43. No brooms were removed within the surrounding 'uncontrolled' areas, except from trees which were recorded for witches' broom incidence.

River Estate Experiment, 1941-42

The fields included in the 'controlled' area where brooms were removed, comprised approximately 80 acres. Adjacent and surrounding fields formed the 'uncontrolled' area, totalling about 140 acres, where no brooms were removed.

The removal of brooms began in April 1941 and was completed at the end of August 1941. There was no second removal of brooms later in that year. The monthly observations on the marked trees began in July 1941 and ceased in March 1942.

River Estate Experiment, 1942-43

The 'controlled' area was reduced in size to 25 acres, with a surrounding 'uncontrolled' area of approximately 62 acres. Therefore, in the second year the 'controlled' area was considerably smaller than that of the previous year, but it was more compact and in that respect better suited for the purposes of the experiment than was the larger area of 1941-42.

The removal of brooms began in March 1942 and was completed at the end of May 1942. It should be noted that the cutting began and finished earlier than in the previous season.

There was a second removal of brooms on 12 acres of the 'controlled' area in November and December 1942. The monthly recording of brooms began in July 1942 and ceased in March 1943.

Phillipine Estate Experiment, 1941-42

The 'controlled' area consisted of three fields containing approximately 12,000 trees (40 acres) in a compact block which was roughly rectangular. No brooms were removed from the trees in the surrounding 'uncontrolled' area, which was approximately 50 acres in extent.

The removal of brooms began in June 1941 and was completed in the middle of August 1941. There was a second removal of brooms in October and November 1941. The monthly recording of brooms began in September 1941 and ceased in March 1942.

Phillipine Estate Experiment, 1942-43

The fields used for the 'controlled' and 'uncontrolled' areas in the 1942-43 experiment were the same as those included in the 1941-42 experiment.

The removal of brooms commenced in March 1942 and was completed in the following month. There was a second removal of brooms in October and November 1942. The monthly recording of brooms commenced in June 1942 and ended in March 1943.

Monthly Records of Witches' Broom Disease

It was originally intended that there should be 250 recorded trees chosen at random within the 'controlled' areas on each of the two estates and a similar 250 trees in the 'uncontrolled' surrounding areas. This was achieved at Phillipine Estate in both seasons, but at River Estate in 1941-42 it was necessary through unforeseen circumstances, to allocate 209 recorded trees for the 'controlled' area and the remaining 291 trees for the 'uncontrolled' area. The trees recorded in 1941-42 were not again used for this purpose in the following season, entirely new

Table I.—Summary of Records from Marked Trees

Month	'Controlled' Area					'Uncontrolled' Area				
	No. of brooms	Average No. of brooms per tree per month	No. of Witches' broom pods	No. of healthy pods	Pod infection per month %	No. of brooms	Average No. of brooms per tree per month	No. of Witches' broom pods	No. of healthy pods	Pod infection per month %
River Estate 1941/42										
July ...	3765	18.0	8	182	4	15409	53.0	41	131	24
August ...	2126	10.2	0	41	0	4705	16.2	2	46	4
September ...	2165	10.4	27	4	87	4136	14.2	8	8	50
October ...	1926	9.2	12	17	41	3287	11.3	12	9	57
November ...	874	4.2	29	36	45	1930	6.6	38	38	50
December ...	1202	5.8	45	158	22	4997	17.1	88	259	25
January ...	4575	21.9	213	239	47	8214	28.2	191	248	44
February ...	2036	9.7	131	134	49	4191	14.4	203	111	65
March ...	2886	13.8	65	91	42	5822	20.0	83	78	52
Total ...	21555	11.5	530	902	37	52691	20.1	666	928	42
River Estate 1942/43										
July ...	2266	9.1	45	1871	2	1321	5.3	15	1375	1
August ...	2324	9.3	1	34	3	2230	8.9	2	26	7
September ...	4548	18.2	12	4	75	3873	15.5	1	0	100
October ...	4363	17.5	17	18	49	3089	12.4	5	17	23
November ...	7282	29.2	73	11	87	8637	34.6	15	1	94
December ...	13186	52.7	243	49	83	11701	46.8	56	18	76
January ...	9896	39.6	172	302	36	7960	31.8	65	129	34
February ...	2706	10.8	134	152	47	5377	21.5	30	46	40
March ...	6390	25.6	136	140	49	5720	22.9	65	33	66
Total ...	52961	23.5	833	2581	24	49908	22.2	254	1,645	13
Phillipine Estate 1941/42										
September ...	748	3.0	10	9	53	1161	4.6	2	1	67
October ...	420	1.7	17	12	59	382	1.5	0	0	0
November ...	375	1.5	0	5	0	764	3.1	12	11	52
December ...	244	1.0	6	102	6	538	2.2	22	133	14
January ...	77	0.3	5	136	4	589	2.4	46	111	29
February ...	171	0.7	14	155	8	1236	4.9	79	253	24
March ...	99	0.4	20	422	5	776	3.1	93	286	25
Total ...	2134	1.2	72	841	8	5446	3.1	254	795	24
Phillipine Estate 1942/43										
June ...	179	0.7	4	529	1	212	0.8	2	153	1
July ...	74	0.3	3	213	1	221	0.9	3	58	5
August ...	135	0.5	4	11	27	180	0.7	0	20	0
September ...	215	0.9	6	15	29	201	0.8	0	1	0
October ...	278	1.1	4	3	57	340	1.4	5	5	50
November ...	515	2.1	22	14	61	419	1.7	9	3	75
December ...	374	1.5	19	98	16	303	1.2	12	73	14
January ...	454	1.8	102	166	38	435	1.7	31	179	15
February ...	345	1.4	70	99	41	355	1.4	83	295	22
March ...	432	1.7	49	401	11	744	3.0	84	363	19
Total ...	3001	1.2	283	1549	15	3410	1.4	229	1150	17

sets of recorded trees were taken for the 1942-43 experiments. Observations were made on all of the marked trees once every month. The brooms were recorded separately according to their type, in the following four classes :—

(1) All vegetative brooms (fan and chupon)
(2) Cushion brooms
(3) Star brooms
(4) Witches' broom infected pods
(5) Healthy pods were also recorded

Observations

Each experiment, as judged by observations on the recorded trees, was assumed to commence in the month following the completion of the removal of brooms in the 'controlled' area. The experiment was concluded each season when the recording of the marked trees in March had been completed.

Objective

The purpose of the experiments was to determine whether the cutting of brooms in the 'controlled' areas had the beneficial effect of producing a lower level of disease incidence within the 'controlled' area, as compared with the 'uncontrolled' area.

This comparison is made on the basis of the brooms and pod infections recorded for the observed trees in the two areas, as summarized in Table I.

Results

The first season of the experiments produced indications that the large-scale clearances of brooms in the 'controlled' areas were effective in causing a lower disease incidence, both as regards brooms and pod infection (Table II).

The repetition of the experiments in 1942-43 gave negative results (Table II), there being apparently higher infection in the 'controlled' as compared with the 'uncontrolled' area at River Estate. In the case of the Phillipine Estate experiment in 1942-43, the difference between 'controlled' and 'uncontrolled' areas is insignificant so that the cutting of brooms cannot be said to have had any effect on disease incidence in that season.

Table II.—Showing Witches' Broom Disease Comparisons between 'Controlled' and 'Uncontrolled' Areas at River and Phillipine Estates in Two Seasons

	No. of brooms	No. of trees	Mean No. of brooms per tree	Standard Error of the mean (S.E.)	No. of Witches' broom pods	No. of healthy pods	Total pods	Pod infection %
RIVER ESTATE 1941/42								
'Controlled' Area ...	21555	209	103.1	6.86	530	902	1432	37.01
'Uncontrolled' Area ...	52691	291	181.1	10.14	666	928	1594	41.78
Diff. between the means ...			78.0	12.24	Diff. between the percentages			4.77
Difference/S.E. of difference				6.4, Significant				
RIVER ESTATE 1942/43								
'Controlled' Area ...	52961	250	211.8	14.20	833	2581	3414	24.40
'Uncontrolled' Area ...	49908	250	199.6	8.45	254	1645	1899	13.38
Diff. between the means ...			12.2	16.52	Diff. between the percentages ...			11.02
Difference/S.E. of difference				0.7, Not Significant				
PHILLIPINE ESTATE 1941/42								
'Controlled' Area ...	2134	250	8.5	0.72	72	841	913	7.89
'Uncontrolled' Area ...	5446	250	21.8	2.36	254	795	1049	24.21
Diff. between the means ...			13.3	2.46	Diff. between the percentages			16.32
Difference/S.E. of difference				5.4, Significant				
PHILLIPINE ESTATE 1942/43								
'Controlled' Area ...	3001	250	12.0	0.93	283	1549	1832	15.45
'Uncontrolled' Area ...	3410	250	13.6	1.57	229	1150	1379	16.61
Diff. between the means ...			1.6	1.83	Diff. between the percentages ...			1.16
Difference/S.E. of difference				0.9, Not Significant.				

The 'controlled' area at River Estate was reduced from 80 acres in 1941-42 to 25 acres in 1942-43, but even in the first season the results were not conclusive as regards achieving the aim of the experiments.

A 'controlled' area of the same intermediate size (40 acres) was employed at Phillipine Estate in both seasons, the first giving positive, and the second, negative results. The levels of disease incidence have remained relatively constant for each estate in the two seasons as shown in Table III.

TABLE III

General Incidence of Witches' Broom Disease ('Controlled' and 'Uncontrolled' Areas Combined) for the Two Estates in Two Seasons

	River Estate		Phillipine Estate	
	1941-42	1942-43	1941-42	1942-43
Mean Number of Brooms per Tree per Month ...	16.5	22.9	2.2	1.3
Per cent. Loss of Pods (Witches' Broom Pods × 100/Total Pods)	39.5%	20.5%	16.6%	16.0%

It would appear therefore, that within the range of areas employed (25 to 80 acres) the smaller 'controlled' area in 1942-43 cannot be held responsible for the negative result at River Estate, since such an explanation is not admissible in the case of Phillipine Estate where the 'controlled' area was 40 acres in both seasons. The general incidence of brooms appears to have been slightly greater at River Estate in 1942-43 when compared with 1941-42, but not so as regards pod infection. The same fields constituted the 'controlled' area for two seasons at Phillipine Estate when it might be expected that there would have been greater reduction of disease rather than less, as actually happened, in the second season.

Discussion

I. The Possibility of 'Border Effect'

It was originally considered advisable that the 'controlled' areas should be larger than was actually achieved in these experiments. Previous observations (1) were then considered to indicate that locally intense spread of *Marasmius perniciosus* spores from a highly infected centre might be serious for a distance of about 100 yards. It might have been expected therefore, that in the periphery of the 'controlled' area, the incidence of brooms would be greater than towards the centre. If such were the case, then a zonation of broom incidence should be detected in the distribution of the recorded trees. In order to test this possibility, the relative positions of the recorded trees were plotted with representations of their individual counts of brooms, on plans of the experiment areas in the two seasons. There was no indication from the resulting diagrams that there was any zonation of broom incidence in respect to relative proximity of the 'uncontrolled' surround trees.

The present observations therefore do not support the previous indications (1) that a centre of infection might seriously affect the adjacent cacao for a distance of only about 100 yards.

The earlier observations were made on an area of less than two acres, as compared with the much larger areas of 25, 40 or 80 acres which have been considered in the present case. Further, it may be said that the examination of the present data does not show any indication that trees from which no brooms are removed have a harmful effect on the neighbouring ones, as regards relative incidence of witches' broom disease.

The absence of 'border effect' indicates that there was no appreciable width of periphery (say 100 yards) with higher infection which might otherwise have comprised too great a proportion of the whole 'controlled' area.

II. Individual Variation of the Recorded Trees

As regards numbers of brooms per tree, there was great individual variation amongst the marked trees observed at both estates. The range of variation in number of brooms was much greater for the trees at River Estate than for those at Phillipine Estate.

There were no individuals without any brooms amongst the 500 marked trees in either season at River Estate. On the other hand, 4 per cent. of the marked trees at Phillipine Estate in 1941-42 and 3 per cent. in 1942-43 were free from brooms.

III. Sampling of the 'Controlled' and 'Uncontrolled' Areas

As explained above, it was intended that there should be 250 recorded trees situated within both the 'controlled' and 'uncontrolled' areas. In order to gain information as to whether this number of 250 was a suitable choice, the data were subjected to random sub-sampling and analysis. As a result of this examination of the figures, it was found that the numbers of trees in the samples (291,250 or 209) were not too small. The samples could apparently have been smaller, down to a limit of 150 trees per sample when the results would still have been similar to those obtained with the larger samples.

Conclusions

Experiments have been described which were carried out to determine whether direct control of witches' broom disease could be achieved on the field-scale by thoroughly removing brooms once or twice in the year, during those months

which seemed likely to be most efficacious. Although there was some apparent benefit in the first season, this result was not confirmed in the following season.

There do not appear to be any grounds on which the 1942-43 experiments can be discounted in favour of the previous seasons results, the only conclusion to be drawn therefore, is that the removal of brooms is not effective in controlling the disease, on areas of 25, 40 and 80 acres, as carried out in these experiments. It appears that control of witches' broom disease cannot be effectively applied along such lines, whilst it seems unlikely that other and practicable methods of direct control will be discovered. Efforts towards controlling witches' broom disease should therefore now be concentrated on the production of resistant varieties of cacao.

Summary

1. A possible means of controlling witches' broom disease is considered. This method was based on observations of the seasonal variations in the appearance of brooms and sporophores (mushrooms).

2. Earlier procedures for control by the removal of brooms are described.

3. Experiments were conducted at two estates for two seasons with the object of determining whether direct control is effective over relatively large areas when brooms are removed once or twice only in the year, namely in the period April to June, and also in October to November.

4. The experiments were assessed by sampling within the two areas, where brooms were removed ('controlled' area), and allowed to remain on the trees ('uncontrolled' area) respectively.

5. There were 500 sampled trees for each experiment, this number being shared between the two areas.

6. In the first season there was some apparent benefit from the removal of brooms but this result was not repeated in the second season when there were no significant differences in favour of the 'controlled' areas.

7. Within the 'controlled' areas of 25, 40 or 80 acres, there were no zonations of broom incidence in relation to proximity of the trees in the 'uncontrolled' areas, where brooms were left on the trees.

8. The range of variation in number of brooms per tree was greater at River Estate where the disease was more severe.

9. The number of recorded trees was apparently adequate.

10. It is concluded that the removals of brooms either once or twice in the year, on areas of 25, 40 or 80 acres in the period 1941 to 1943, were not effective in controlling the disease.

11. It is recommended that efforts should now be concentrated on the production of types resistant to witches' broom disease.

Acknowledgment

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References

(1) Baker, R. E. D., Crowdy, S. H., and Thorold, C. A., (1941).—Witches' Broom Disease Investigations. I.—Seasonal Variations in Intensity of Infection and Their Effect on Control Methods. *Tropical Agriculture*, Trinidad, **18**: 107-116.

(2) Annual Report, Department of Agriculture, Trinidad and Tobago, for the year 1931 (1932): 12 and 54.

(3) Annual Report, Department of Agriculture, Trinidad and Tobago, for the year 1932 (1933): 5 and 47.

(4) Annual Report, Department of Agriculture, Trinidad and Tobago, for the year 1937 (1938): 65.

(5) Gilbert, S. M., (1932).—Report on Special Witch-broom Control carried out in Turure and Tamana Wards, in May and June 1932: Trinidad 1-20.

(6) Pound, F. J., (1938).—Cacao and Witchbroom Disease *Marasmius perniciosus* of South America, Trinidad: 10.

APPLICATION OF NITROGENOUS MANURES TO COTTON

Remarkably high yields of cotton have been reported as the result of applying sulphate of ammonia as manure for the cotton crop according to a special method (R. J. Kalamkar in *Nagpur Agr. Coll. Mag.*, 16, No. 4). The method consists in coating the cotton seed prior to sowing with dry sulphate of ammonia powder, the seed itself being moist with the wet paste of earth and cowdung which is usually rubbed over it to paste down the fuzz and make the seed run freely through the drill. This method was compared with (i) applying the same dose of sulphate of ammonia as a top-dressing three weeks after sowing and (ii) applying one half the dose by drilling it with the seed at sowing time and the other half as a top-dressing three weeks after sowing and (iii) control. The seed rate per acre was 20 lb. and the sulphate of ammonia used was at the rate of 10 lb. of nitrogen or the equivalent 50 lb. of ammonium sulphate per acre. The trials were conducted at the Government Seed and Demonstration Farm at Khandwa and the variety of cotton was V. 434. The experimental plots were laid out in a randomised block with five replications. The results show that a very high and significant increase in yield was obtained by the method of coating the seed with the fertiliser and that this increase in yield amounted to 66 per cent. over the control. The other two methods also gave increased yields of 14 to 18 per cent., but these increases were not statistically significant.—(*Current Science*, Vol. XI, No. 12.)

THE EFFECT OF DIFFERENT LOCALITIES ON THE GROWTH OF SUGAR CANE VARIETIES

Sugar cane is successfully grown at the present time under a very wide range of environmental conditions: it is a crop with very simple agricultural requirements. Although it is essentially a tropical plant, many important cane-growing districts are well outside the tropics, for instance, the Argentine and Louisiana. Such districts require a particular variety type. With regard to rainfall, sugar cane can generally be grown without irrigation anywhere where this is over 50 inches per year, provided a definite rainy season is available for growing the crop, and a dry one for ripening and harvesting it. In parts of Hawaii, more than 1,000 feet above sea level, the rainfall reaches 275 inches per year, probably one of the wettest regions where sugar cane is grown. It is difficult to say what is the optimum rainfall for cane growth, because so much depends on local conditions. Leaving other factors out of consideration, it is probable that about 100 inches per year will give as good or better results than any greater quantity, provided it is properly distributed.

The effect of temperature on sugar-cane growth is complicated. Rate of growth, time to maturity, and final composition of the harvested cane (including "richesse" and percentage of reducing sugars) are all affected. In places where there is little temperature range, with no cool season, continuous vegetative growth takes place, and a crop low in sugar content and high in reducing sugars is the result. On the other hand, outside the tropics, such as in Louisiana, the period of growth is so limited as to prevent the cane reaching maturity. The ideal climate requires a relatively long growing period, followed by a season sufficiently cold to check vegetative growth and to encourage ripening. Such conditions are most frequently found near the outer limits of the tropics, and the richest and purest crops are obtained where dry weather accompanies this cool ripening season.

It will be evident that few of the sugar-cane areas fulfil all these conditions; also the range of soil-types on which the cane is grown introduces another factor. The problem is, how the various types of environment under which sugar cane is grown in different localities can be suited by the range of varieties available. Even in a small place like Mauritius, there are great variations between the average conditions of different cane-growing districts. Even in one place, conditions may vary considerably from year to year, and in considering the suitability of varieties, we must work on the *average* conditions over a number of years, for these represent the highest probability of what is to be expected in future.

Varieties of sugar cane differ from one another in many respects; under a given set of conditions, certain varieties may be successful while others fail. What concerns us is why this should be so, and in what ways varieties differ from one another, so as to make them specially suitable for particular conditions.

The following are some of the more important ways in which variety types may differ:—

(1) The number of tillers (or new shoots) produced, and particularly the time of their emergence.

(2) The rate of growth of the canes.

(3) The length of the vegetative growth cycle, that is, the length of time which the canes will continue to grow under favourable conditions without arrowing or slowing-down in growth. Generally speaking, heavy arrowing varieties have a short vegetative growth period (although during the period, growth may be very rapid), and varieties which arrow little or not at all have a long one.

(4) The rate at which ripening takes place, and the final quality of the canes.

(5) Extent of resistance to diseases and pests.

As examples of the way in which sugar-cane geneticists have been able to make use of these differences in variety type, the characteristics of the varieties now grown commercially in the two widest extremes of conditions experienced in sugar-cane cultivation may be considered.

In Louisiana, United States of America, where commercial cultivation extends more than 30° north of the Equator, the time during which temperature is high enough for cane growth is comparatively short. The cane is cut 8 to 10 months after planting, and moreover, as conditions are not good for ripening, the crop is always cut immature. Cane of 8 or 9 per cent. sugar content is regarded as good in Louisiana. The harvest has often to be hurried along on account of frost, which kills the standing cane although unless very severe, does not injure the underground buds, so that ratooning is possible. Mosaic disease and Red Rot are severe in Louisiana on susceptible varieties. Under these rather exacting conditions, a special type of variety is necessary. Some varieties were bred at the Canal Point Station in Florida, and some were introduced from Coimbatore, where they had been raised for somewhat similar conditions in Northern India. In general, these varieties are canes in which tillering is abundant, and takes place early in the growth cycle, so that a large number of canes is ready to make use of the growing conditions as soon as they arise. Tillering then ceases, so that all the canes in the crop are of approximately the same age, and there are few late-produced young canes which would bring down the average richness of the crop. Growth of the individual canes is very rapid, so that the best use is made of the short growing season available. Conditions for ripening in Louisiana however are unfavourable; these varieties are

*Abridged version of an article by G. C. Stevenson published in the *South Afric. Sug. Jour.* Vol. 26, No. 9, 1942.

early maturing, and have a short vegetative growth cycle, and therefore are more likely to ripen than varieties in which the vegetative growth cycle is longer. On account of their short vegetative growth cycle, these varieties are really heavy arrowing canes, but arrowing does not occur on the North American continent any further north than Florida.

Concerning the breeding of these canes, they are generally hybrids containing the blood of one or more wild canes, from which resistance or tolerance to mosaic disease is inherited. An American expedition to Turkestan in 1936 found a wild sugar cane species which is resistant to freezing weather. This was introduced to the United States, where it resists temperatures as low as 15° F. It has been crossed with commercial canes with the idea of obtaining new varieties capable of withstanding cold temperatures, and thus being able to begin growth in the spring before those now in cultivation.

Although Louisiana is an extreme example of such conditions a somewhat similar variety type is grown in most sugar-cane regions outside the tropics, such as Argentina, Egypt, Northern India, and Natal.

Co. 290 :— What happens when varieties of this type are grown in the tropics, where the growing conditions are longer, should be well known to those who have tried the Co. 290 cane.

This stops its first growth period early, and arrows heavily, and where growth conditions are still good, produces a second crop of young canes which have no time to ripen, and the result is poor "richesse" when cut.

As examples of the opposite type of environment for sugar-cane growth, a place like Cuba may be cited. Here, temperatures are favourable, being well inside the tropics, and the growth season is a long one, with satisfactory rains from May to October. There is a well-marked dry season, so that ripening conditions are good. Evidently a very different type of variety will be most suitable here. Of greatest importance is the length of vegetative growth period in the canes : one does not want canes which cease growth and produce arrows while conditions are still favourable for two or three feet more growth, and it is important that tillering should take place early in the season, for canes produced over a period of two or three months have plenty of time to make good growth and the good ripening conditions will go a long way to prevent the deleterious effect of younger canes on the average "richesse" of the crop. At the present time, noble canes of the B.H. 10(12) type are most suitable for these conditions. They do not produce superfluous tillers in the early stages, and can make use of the long growing season without arrowing. They are generally rather slow starters, and are of little use where the growing period is a short one. On the dry leeward slopes of the Hawaiian Islands, varieties of this type are grown under irrigation for periods of up to twenty-four months, and crops of 100 tons of cane and 14 tons of sugar per acre are by no means uncommon. The variety H.109 has given almost 150 tons of cane per acre under these conditions in Hawaii.

From the breeder's point of view, it is interesting that at the present time new *hybrid* varieties are being produced, whose vegetative growth cycle is as long as that of the noble cane varieties ; these have a certain proportion of wild blood ; they are vigorous types and will be of particular importance where disease resistance has been a limiting factor to noble cane cultivation. The latest reports from the British West Indies Breeding Station in Barbados indicate that such long-season nobilized seedlings show very great promise, and it is suggseted that they will completely replace the noble canes before so very long.

THE RIPENING COCONUT

Studies on the growth of the ripening coconut and principally with reference to the changes undergone by the fibre throw interesting light on the formation and the progressive changes in composition of the other important and really the main coconut product, the kernel itself (S. R. K. Menon, *Ind. Jour. of Agr. Sci.*, 12, Part III). The method of study consisted in selecting one particular bunch on a tree and following the changes from the very infancy of the fruit to its ripe stage, three such trees being selected for the purpose of confirmatory results. The results confirm the correctness and the wisdom of the present practice of gathering only coconuts which are not fully ripe when fibre production is an important objective. Where oil is the important consideration the nuts have to be gathered at a much later stage, so that the interest of the oil and coir industries are opposed to each other. Taking the particular points studied, it is seen that as regards the volume of the fruit and the weight, the increases are equal during the first six months and then the rate for the volume becomes slow and later begins to diminish. On the other hand, weight begins to drop sharply after the same period until it is only one half of the maximum reached. The water in the nut increases rapidly and reaches a maximum in about three months, after which it declines steadily and sharply until it is only about a seventh part of the maximum in the tenth month. As regards the kernel it begins to form only after the first three or four months but once begun the growth is very quick, reaching a maximum in the ninth or tenth month, after which the change consists only in an increase of density, when the formation of fat becomes vigorous. Ultimately the moisture content falls and the gross weight also registers a decline ; the fat content is said to go on increasing to the last days of the growth of the fruit. The fibre as it matures increases in lignin and loses both colour and gloss practically until the very last stages of growth ; the non-lignin content increased up to the sixth month steadily, but became more or less stationary thereafter. The picking of the nut when not fully ripe therefore results in a fibre of high non-lignin content and a low-lignin content.—(*Current Sc.*, Vol. II, No. 12)

CHEMICAL NOTES

(Compiled by the College Department of Chemistry and Soil Science)

Aerobic Denitrification in Soils

Losses of nitrogen from tropical soils were formerly ascribed to anaerobic denitrification, but such losses have been reported to occur under *aerobic* conditions. The rapid loss in nitrogen observed in tropical soils following clear felling of forest has been attributed to accelerated micro-biological activity resulting from exposure to higher temperature of direct sunlight. Pot experiments by Wilshaw lend no support to this view, since little of the loss was recovered as soluble nitrogenous compounds in the leachings. The inference is that the loss is largely gaseous nitrogen. In this paper, it is shown that the loss is not due to physical conditions, such as exposure to high temperatures, alternate wetting and drying at 30-50 °C., aeration, or ultra-violet light. Incubation with continuous aeration for seven days of mixtures of sterilized soil with aqueous solutions of ammonium sulphate and potassium nitrite caused little alteration, but when the soil was not sterilized, there was a large loss which, apart from some ammonia evolved, could only be explained as due to evolution of gaseous nitrogen. There was a marked increase in Kjeldahl-nitrogen, and decrease in ammonia and nitrite-nitrogen.

It was also found with fresh samples of two different types of soil (forest and calcareous) that, while the micro-flora present effected the conversion of ammonia-nitrogen in sterilized Reader's medium (glucose) into organic form without nitrogen loss, the substitution of nitrate for the ammonia-nitrogen was followed by significant losses. This was further confirmed in the case of a garden soil where no losses took place on incubation and aeration for 21 days with added nitrite or nitrate, unless organic matter (in the form of glucose), readily available for bacterial synthesis, was also added. In the presence of ammonium sulphate, loss took place. Carbon-nitrogen ratio of the glucose-treated soil was increased in these experiments from 10.6 to 13.9, but from previous evidence it is known that this ratio in itself is not the factor controlling losses of nitrogen, although in a general way it reflects the proportions of biologically-active carbon and nitrogen compounds present.

It is possible that, in tropical areas which are suddenly exposed to sun and rain by felling of forest, organic-nitrogen may be converted into nitrite-nitrogen by a photo-chemical or physico-chemical process, leaving a soil residue of high carbon-nitrogen ratio with excess carbonaceous matter readily available to the micro-flora. Such conditions would lead to nitrogen-impoverishment, and the process would be continuous, the nitrite produced during the day being decomposed biologically during the night, with liberation of gaseous nitrogen.

Thus it is shown by this work that a biological mechanism exists in soils which is able to effect aerobic losses of nitrogen in the presence of (1) a supply of carbonaceous material suitable for the synthetic and energy requirements of microbial growth, and (2) nitrite and/or nitrate as the most readily available source of nitrogen.—(From Paper by A. S. Corbet and W. R. Woolridge in *Biochem. Journ.*, Vol. XXXIV, No. 7, p. 1036.)

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Soil Conditions Affecting Production of Perithecia in Banana Leaf Spot Disease*

Recent research (1) has brought to light the existence of the ascigerous stage (*Mycosphaerella musicola*) of the fungus *Cercospora musae*, during studies on the etiology of leaf spot or ' Sigatoka ' disease of bananas. Perithecial formation is mainly seasonal, being greatest between August and January.

Experiments have shown that three-weekly spraying cycles, for example, with 4-4-40 Bordeaux mixture, are unable to control banana leaf spot satisfactorily unless the disease is brought under control before the start of the ascospore season. This applies to almost the whole of the banana-growing districts in Jamaica.

In a few isolated areas, however, it has been found that perithecia are produced in profusion throughout the year. A recent survey of these areas has shown that this ' out of-season ' production of perithecia is positively correlated with the growth of banana plants on highly acid soils (pH 4.0-4.75 approximately). Regular three-weekly spraying has likewise failed to give satisfactory control of the disease at any time throughout the year. Only by employing the weekly heart-leaf spraying method (2) has control been obtained. This method is impracticable once the plants have grown tall ; unless liming or some other means can be found to ameliorate the effect of high soil acidity on the metabolism of the Gros Michel banana and its parasite (*M. musicola*), spraying will prove useless as an economic measure of controlling this leaf spot disease under these conditions.

No experimental data are at present available to explain this physiological problem. It is possible that the water relationship of the soil may also be found to play a part in this abnormal production of perithecia. A search through available literature has failed to disclose a similar example of soil conditions affecting the fructifications of a leaf spot fungus.

*Letter published in *Nature*, Vol. 151, No. 3824, p. 199.

(1) Leach, R.—*Trop. Agriculture*, **18**, 91 (1941).
(2) Leach, R.—" Banana Leaf Spot—When to Spray and Why ". (Dept. of Agriculture, Jamaica, 1942.)